# Concerted Action for Offshore Wind Energy Deployment (COD): Grid Integration of Offshore Wind Farms

by
Concerted Action Offshore Wind Energy Deployment (COD)

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## Abstract

The objective of the European Concerted Action on Offshore Wind Energy Deployment (COD) is to speed up the responsible deployment of offshore wind energy in the EU by early identification and possibly to remove not explicitly technical barriers: legal, administrative, policy, environmental and grid infrastructure planning issues. The COD is carried out by eight sea-bordering member states, represented by their energy agencies or delegated third parties.

Main points of concern for the connection of offshore wind farms to the national power systems are transmission bottlenecks, power system stability, offshore transmission infrastructures and grid access, pricing and balancing. Moreover the grid integration of offshore wind energy is strongly affected by the possibilities for Trans-European power exchange.

The situation in the eight participating countries has been reviewed and conclusions have been drawn. These are further elaborated these in order to arrive at generalized observations, recommendations for policy makers, and issues that will emerge in the near future. The main conclusions and recommendations are:

- Grid reinforcements are necessary in order to facilitate the grid connection of offshore wind farms in the future; however, they require very long lead times. High-voltage DC links on shore may be an alternative to new overhead lines.
- In wind transmission grid codes there is a trend towards active control of large wind farms within the boundaries of the legal frameworks. This contributes to grid stability although some contractual issues are still unclear. The capabilities required from large wind farms should be harmonized with TSO-specific set points.
- Common offshore cables bundling several wind farms would be beneficial. Moreover they can become initial nodes of an international offshore grid. Up to now no bundling happens.
- Grid access, energy pricing and balancing are interrelated. Concepts to increase the value of wind energy comprise adapted demand control, back-up generation or storage. Furthermore, good short-term forecasting will increase the value of wind energy on energy markets.
- In order to take advantage of the spatial decorrelation of wind speed, transmission of wind power must be possible over distances comparable to the extensions of meteorological systems. Strong Trans European networks are essential for this purpose, but the economic case for such networks (in comparison to competing options) is not yet clear.

In conclusion, many things need to be done on a technical level in order to integrate large amounts of offshore wind power into our power systems. However, none of these measures is technically unknown. Therefore, the feasibility of integrating large amounts of offshore wind power is mainly a question of finance, and hence based on political decisions or depending on a favourable framework.

# 1 Introduction

## 1.1 Concerted Action for Offshore Wind Energy Deployment

The Concerted Action for Offshore Wind Energy Deployment (COD) aims to progress offshore wind energy in the European Community by sharing and incorporating good practice in legislation and consents procedures; environmental impact assessment and mitigation, and grid integration. The COD exchanges information between the national energy agencies of most sea-bordering member states of the European Union. In the COD the energy agencies or delegated third parties from Belgium, Denmark, Germany, Ireland, the Netherlands, Poland, Sweden and the United Kingdom are co-operating; representing more than 90% of the offshore wind energy potential in the EU.

COD interacts with key actors through an Advisory Board. The COD activities are steered by a Ministerial Working group with representatives of the energy departments of the participating countries.

## 1.2 Grid Integration of Offshore Wind Farms

Barriers affecting the connection of offshore wind farms to the national power systems are one major topic of the COD project. The main areas of emphasis are transmission bottlenecks, power system stability (and grid code requirements which seek to address this), offshore cable connections, grid access, energy pricing, and aspects of Trans-European power exchange.

The COD wants to provide an overview of national grid characteristics and studies on grid integration of wind energy. This should lead to a better utilisation of the transmission system; timely plans for required system modifications and reinforcements; and adoption of system planning and operational practices which properly assess and reflect wind energy's characteristics – in turn leading to high values in power markets.

## 1.3 Approach

In most of the participating countries, some or all of these subjects have been studied by government bodies or transmission system operators (TSOs). These studies from the eight participating countries have been reviewed by COD, with a focus on the relevant grid issues. The results of this review can be found, country by country, in the final COD grid report [1].

From these country summaries, it is possible to group countries by shared grid-related characteristics. COD has then gone on to make conclusions and recommendations to support the removal of grid as a barrier to offshore wind deployment. While actions required are for the most part similar across Europe, the emphasis and approach will vary according to the technical characteristics of the grid system, as well as political and market oversight of grid access and pricing.

# 2 Country Groupings

From the analysis of information from the eight countries a number of issues can be identified that are common to several of these countries. Depending on the geographical situation or historically evolved grid topologies, countries can be clustered according to the synchronous zone to which their power system belongs. The different control zones in Europe are indicated in *Figure 1*. These clusters of countries correspond to a large extent to the regions between which there is limited mutual exchange capacity, as indicated by the priority axes of the European TEN-E [2].

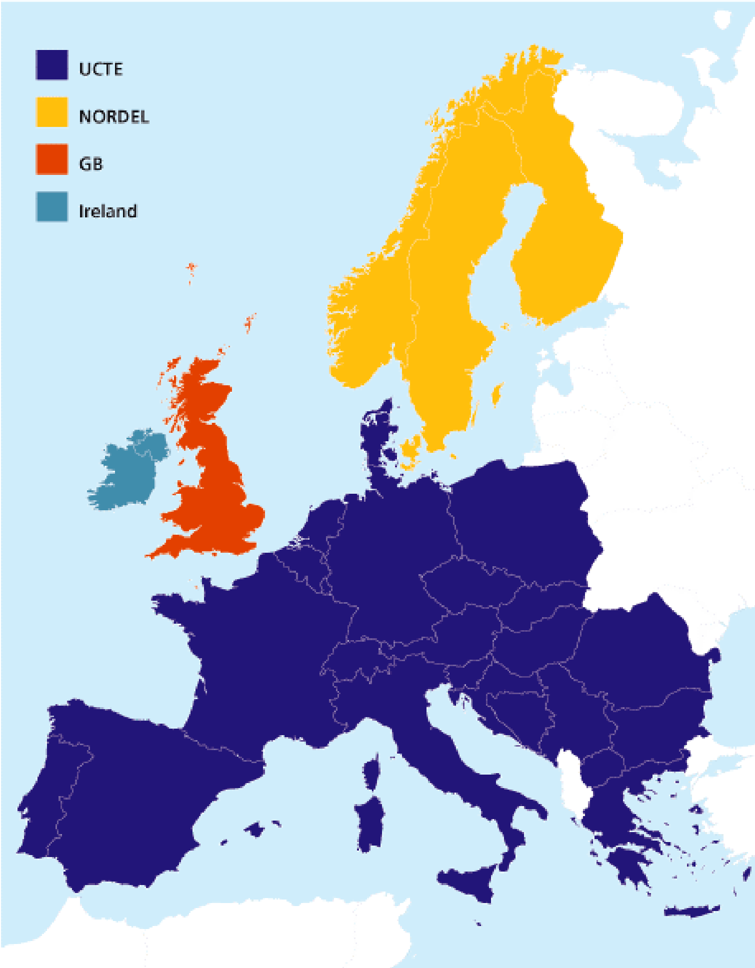


*Figure 1: Synchronous zones in Europe (source ETSO)*

### 2.1 Central and Western Europe

Belgium, the Netherlands, Germany, Poland and the western part of Denmark make part of the UCTE grid. This grid is highly meshed and contains a large traditional generation capacity providing high short-circuit power. The grid is very stiff. Therefore, the impact of offshore wind power on the grid frequency is generally not considered a problem. In addition, the problem of voltage control is considered minor if in the future wind turbines with reactive power control and voltage ride through capabilities are applied.

With exception of the coast of Holland, the coastal areas in Central and Western Europe are rural. Industrial areas are typically situated inside the country. Therefore, in these countries, energy from offshore wind farms will have to be transported to the load centres. On its way through the transmission system this power often has to compete for transmission capacity with power imported from abroad or on transit.

Power injection from offshore wind farms in these countries is limited by the availability of large substations in the coastal regions and by the transmission capacity to the load centres. The necessary grid reinforcements in Germany, the Netherlands and Belgium have already been identified. Adequate grid reinforcements are under consideration, including innovative approaches such as long high-voltage DC cables to form an overlay grid onshore. The main uncertainty for offshore wind energy is the timing of these reinforcements. In particular, the permitting procedure for 400-kV overhead lines can be very protracted, and uncertain. In this situation, TSOs will initiate the required major grid reinforcements only when substantial applications for grid reinforcement have been filed. On the other hand, project developers will make considerable investments only when the grid connection of a wind farm at the time of commissioning can be guaranteed.

## 2.2 The British Isles

The power systems of the islands of Ireland and Great Britain each form a separate synchronous zone connected to each other, and to continental Europe, only by weak high-voltage DC links. Therefore, an issue for the grid integration of large wind farms (on- and offshore) is power system stability. As such, in Ireland and the UK, large wind farms are now required to participate in primary (frequency) control, at least in situations where the power system stability is threatened. Moreover, reactive power control and voltage ride through capabilities are specified in grid codes.

In Ireland and the UK grid bottlenecks are also considered an obstacle to offshore wind energy. There is now a transparent process by which new transmission capacity can be built in response to the development of new generation projects, without (as a rule) requiring political intervention. The costs for these reinforcements are not considered an obstacle for wind generation if viewed in the context of total power system costs, although where costs allocated to a particular region or group of projects, grid reinforcements can become a barrier. It is likely that the grid connection of some offshore wind farms could be delayed (or prevented, if planning permission is not granted) because of the time required to obtain permissions and construct new transmission capacity. Squaring the circle of providing investment guarantees for transmission capacity, prior to knowledge on which offshore wind projects will proceed is also a source of delay for initiating work on reinforcements.

## 2.3 Scandinavia

The Danish power system is split into two synchronous zones. In times of low load offshore wind farms connected to the transmission system in the western part of the country together with wind energy onshore add to the power generation in the north of Germany. Power from offshore wind farms connected to the transmission system in the eastern part is injected into the Nordel synchronous zone. The Nordel synchronous zone is characterized by a large amount of hydro power. Hydro power plants can be controlled very fast and they could complement the slower-controllable thermal-dominated generation in the UCTE system. Technically, they could be used to balance fluctuations from wind power in Western Denmark and Northern Germany. However, this is not realised yet practically due to the present settlement model for the power exchange via the high-voltage DC connections between Western Denmark and the Nordel system [3].

In addition, in Sweden offshore wind power will mainly be generated close to the loads, i.e. in the south of the country. Therefore, it has a potential to mitigate congestion of the north south transmission links supplying the south of Sweden with power from the hydro plants in central and northern parts of the country.

### 2.4 Conclusion

A number of issues affecting the grid integration of offshore wind energy have been identified. Some of them are emphasized more or less in different countries depending on characteristic properties of the different power systems (Continental Europe, British Isles, Skandinavia). However, most identified issues are in different ways common to all participating countries. These issues are:

- grid reinforcement,
- requirements from grid codes,
- offshore cables,
- grid access, pricing and balancing,
- Trans European power exchange.

Based on the information gathered in these report, conclusions are drawn for each of these issues. Based on the conclusions, the COD working group has compiled a set of observations and recommendations as well as its expectations for future developments. Some of these issues have already been addressed in the declaration of the EU policy workshop about the development of offshore wind energy in Egmont aan Zee (Netherlands) in October 2004 [4].

## 3 Observations, Conclusions and Recommendations

### 3.1 Grid Reinforcement

There is no doubt that considerable grid reinforcements will become necessary in all participating countries in the coming five to ten years, if aspirations for offshore wind energy are to be met. These reinforcements can take 10 to 15 years due to the long lead times for land acquisition and permits. Although the necessary reinforcements have been documented in some countries, no TSO is preparing the necessary reinforcements in practice.

For a developer, a guarantee for consent of a project, and availability of a timely grid connection, are necessary pre-condition to ordering and financially backing substantial grid reinforcements. However, in accordance with national legislation, TSOs will initiate planning procedures for grid reinforcement only when the reinforcement has been ordered by the developer. Reinforcement must be initiated early in the development process, and is subject to uncertainty. Hence, developers and TSOs are caught in an impasse.

The large-scale deployment of offshore wind energy requires grid reinforcement. The longer this is postponed the more the deployment of offshore wind energy will be retarded. In some cases where a timely grid reinforcement can not be expected, innovative alternatives may be applicable in order to facilitate the grid connection of a wind farm. Such alternatives are dynamic line ratings and high-voltage DC transmission links on shore.

The need to provide early funds for strategic infrastructure is not new, and has previously simply been funded by governments. Under the now liberalised market frameworks, governments should consider ways of removing the impasse between TSOs and developers. Approaches which have been considered and / or used in different EU member states include: government backing up investment made by TSOs until such time as it is utilized; use of European funds to provide strategic infrastructure; or sharing investment risk across electricity market participants.

### 3.2 Grid Codes

Grid codes list the power system operators' requirements for grid connection of plant to the transmission or distribution system – with different requirements and / or parameters for each. Large offshore wind farms will tend to connect increasingly to the transmission system, as opposed to typical European onshore wind farms which tend to be distributed plant.

In all participating countries there is a general trend towards the requirement of active control of large wind farms: the wind farm has to contribute actively to the stability of the power system. In detail, the requirements in the different countries differ significantly regarding the specified set-points for the various control actions, and also in terms of the required capabilities.

Active control typically includes the possibility for the TSO to curtail the wind farm's power output when the grid stability is at risk. This possibility can interfere with the requirement for priority dispatch of electricity from renewable sources, but can also result in more efficient use of existing infrastructure. Power curtailment should only be a temporary measure in order to cover the time period until new infrastructure is built. Since the curtailment of wind farm output power should affect only small amounts of energy, this conflict of interest can probably be solved relatively easily either on a contractual or on a regulatory basis.

In general, curtailment of wind farm output should not be seen as a barrier to priority dispatch. As it has zero fuel costs, wind energy plant should be curtailed only when necessary for stability of the system and if possible only until the necessary infrastructure is built.

The set points required by a TSO typically reflect the circumstances in a given power system. Wind turbine manufacturers find it difficult to adapt the control capabilities of their machines to a number of different sets of requirements in different countries. Therefore, the required control capabilities for large wind farms should be harmonized all over Europe while the specific set-points should also in future be determined by the TSO responsible for the specific power system.

There may well be a conflict between the desire for harmonisation, and the requirement to treat all generators in a non-discriminatory manner. It may not be possible in some countries to agree requirements for wind generation that are more or less onerous than the requirements for other forms of generation. It is therefore possible that complete harmonisation is not feasible, at least in the medium term.

### 3.3 Common Offshore Cables

Studies carried out in different countries show that bundling of offshore cables from several wind farms offshore is beneficial. A multitude of cable ducts crossing the coastal areas and dykes can negatively affect the ecosystem and deteriorate the protection of the coast line. In contrast, the connection of several wind farms via a common cable or cable duct to the connection point onshore contributes to streamlining the procedure for grid connection. Via such a common cable connection the effective grid connection point would likely be situated offshore. In some cases, the bundling of offshore cables can save costs for the cable duct.

Although these advantages are well known, offshore transmission cables from different wind farms are currently not bundled. Although it has been considered, discussions tend to be mired in commercial and regulatory issues. There is a lack of true strategic planning or legal provisions to impose planning of offshore transmission infrastructures in the different countries.

Finally, the bundling of offshore wind farms would lead to radial offshore grid infrastructures. These would be spatially limited in the beginning but they could become the initial nodes of an international offshore grid to emerge by stepwise interconnection.

In order to kick off the development of common infrastructure, its facilitation should be considered in the national and international regulatory framework.

### 3.4 Grid Access, Pricing and Balancing

According to Article 7 the European RES-E directive [5], electricity from renewable sources may receive priority access to the power system, and priority dispatch insofar as the operation of the national power system permits. Respective laws have been introduced in most participating countries; however, the implementation of these requirements into national law is different in each country.

In practice, the decisive factor, besides the physical access to the grid, is the price for electricity from renewable sources on the electricity markets. Priority dispatch is only useful when market parties are willing (or forced by law) to buy electricity from renewable sources at sufficiently high prices.

Especially in countries where renewables are supported via tradable certificates, the revenues for electricity from wind energy depend firstly on the market price for the tradable certificate and secondly on the market value of the remaining brown energy. The certificate value is typically limited by the penalty for unfulfilled quota obligations, and in some countries also by fixed minimum prices. The value of brown energy is determined by the conventional market. Conversely, in countries with fixed feed-in tariffs, the revenues for both brown electricity and green value are determined by law and imposed via the tariff.

Due to the variability of wind energy, this electricity price can be relatively low, especially in countries where imbalance is penalized. In order to increase the market value of energy from large wind farms, good short-term predictions are necessary, possibly in combination with concepts of adapted demand control, back-up generation or storage. Therefore, in order to improve the value of wind-generated electricity, short-term forecasting of output should be supported and developed.

In addition, market arrangements which penalise imbalances should reflect the real cost of imbalance. In some countries imbalance prices are disproportionally high in order to prevent market parties from speculation. However, such high imbalance prices penalize decentralized generation.

### 3.5 Trans European Power Exchange

Historically, interconnections between countries and their power systems were intended for international support in case of contingencies and, to a limited extent, for bilateral trade based on long-term contracts. With the establishment of the internal European electricity market, an increasing fraction of the available capacity is now used for international trade. This latter capacity is mainly traded bilaterally, and not explicitly used for the levelling of power fluctuations introduced by wind energy.

In order to enable wind energy to contribute significantly to power supply all over Europe, the spatial variation of wind power needs to be utilized to the maximum possible extent. Because weather systems can span whole regions at a time, this implies power flows between synchronous zones, and within the UCTE – in particular between the main block and the Southern European countries. To supplement the technical infrastructure, market mechanisms need to be developed enabling international trades as close as possible to real time, to facilitate programmed transfers of wind energy.

Currently transmission capacity between these regions is limited, and it is an objective to reinforce the power system, especially according to a number of priority axes as defined in the European TEN-E action. However, the current version of the TEN-E action sees the importance of cross border transmission capacity for the grid integration of wind energy mainly in the very regions where large increases in wind energy deployment are anticipated. The importance of transcontinental transmission to benefit from the spatial dimensions of meteorological phenomena has not yet been acknowledged. This should be taken into account in the next revision of the TEN-E action.

Transcontinental offshore transmission and overlay grids have been proposed as the most economic measures to increase the share of wind power and other renewable sources that the European power systems can absorb. However, in practice most actors still perceive these concepts as not competitive solutions onshore in the short and medium-term. Possibly, spatially limited radial offshore grids could form the initial nodes of such a grid.

# 4 Overall Conclusion

On a technical level, a number of bottlenecks for the large-scale grid integration of offshore wind energy exist and much needs to be done to remove them. The necessary measures have been identified in previous studies for the specific national contexts. The European Concerted Action for Offshore Wind Energy Deployment (COD) has inventoried the situation in the participating countries and analyzed the future requirements on a European background.

All measures required in order to render the large-scale integration of offshore wind energy in Europe possible are technically known. Therefore, the feasibility of integrating large amounts of offshore wind power in the considered time frame does not pose a technical problem. The barriers to the further integration of offshore wind energy are mainly a question of finance and hence based on political decisions and the creation of a favourable framework.

In practice the removal of barriers to the grid integration of offshore wind energy requires political commitment of governments, a suited regulatory framework and the active participation of TSOs. In general, any short-term solution should fit into a long-term strategic vision.

# References

[1] A. Woyte, P. Gardner, and H. Snodin. *Concerted Action for Offshore Wind Energy Deployment, Work Package 8: Grid Issues*, Offshore Wind Energy Europe, COD, October 2005. http://www.offshorewindenergy.org.

[2] *Trans-European Energy Networks 'TEN-E', Documentation and Reports.* http://europa.eu.int/comm/ten/energy/documentation/index_en.htm, accessed May 2, 2005.

[3] V. Akhmatov, H. Abildgaard, J. Pedersen, and P.B. Eriksen. Integration of Offshore Wind Power into the Western Danish Power System, *Proc. 2005 Copenhagen Offshore Wind International Conference and Exhibition,* Copenhagen, Denmark, October 26-28, 2005, 9 pp.

[4] Declaration - EU policy workshop: Development of offshore wind energy, Egmont aan Zee, Netherlands, October 1, 2004. http://www.offshorewindenergy.org/reports/report_036.pdf.

[5] Directive 2001/77/EC of the European Parliament and the Council of 27 September 2001 on the promotion of electricity from renewable energy sources in the internal electricity market, *Official Journal of the European Communities*, 27 October 2001.

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